Scenarios for a future dairy chain in the Netherlands

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Abstract

The objective of this study was to assess qualitatively, through a participatory approach, the potential for increasing the value added in the Dutch dairy production chain. A workshop involving stakeholders and experts in the Dutch dairy sector developed three scenarios, envisioned according to the strategic interests of the dairy chain in the Netherlands. These scenarios address major trends including changing consumer preferences, increasing pressure for more cost-efficient production, and rising environmental concerns. The scenarios indicate different directions in which the dairy chain in the Netherlands might develop in the next 5 to 20 years. The first scenario envisions the prevalence of producing differentiated raw milk with enhanced health or improved manufacturing properties. The second scenario envisions a dairy chain that is reduced to producing fresher and more individually customized dairy products with improved shelf life. The third scenario envisions ecologically sustainable dairy farming with improved animal welfare. These scenarios show that when improving the dairy sector it is important to consider the entire chain, and hence concerted and co-ordinated actions by the various stakeholders are necessary. Further studies quantifying the consequences of different scenario settings are necessary.

Additional keywords: stakeholder consultation, value added

Introduction

The dairy sector worldwide faces changing consumer demand, a need for greater efficiency and growing concerns over sustainability. First, global demand for dairy products is increasing rapidly, mostly generated by increasing population and purchasing power in developing countries (Delgado, 2003; Dong, 2006). In developed countries, demand for fresh and nutritious foods with improved shelf life is growing (Devlieghere *et al.*, 2004), and the effect of foods on human health is an important factor in consumer purchase decisions (Kaabia *et al.*, 2001; Rickertsen *et al.*, 2003). Second, the dairy sector continuously strives for higher efficiency due to pressure from price- and volume-driven competition in many countries (Creamer *et al.*, 2002). In addition, global dairy trade is likely to become less restricted due to the easing of protectionist policies of some developed countries (Dillon *et al.*, 2008). Third, environmental sustainability concerns become increasingly important, especially those related to greenhouse-gas (GHG) emissions, as cattle farming is a major contributor to methane emission (Creamer *et al.*, 2002). As a result of these trends, the dairy sector continuously looks for innovative solutions to address the trends and increase the value added.

Several methods to increase the value added have been proposed recently. Novel concepts have been investigated at each stage within the dairy production chain. However, less is known about strategies for implementing those value-adding methods and the related implications. Creamer *et al.* (2002) reviewed several developments in the dairy sector and envisioned future directions in which the global dairy sector might develop in the next decades. However, there is no up-to-date study considering strategic opportunities offered by the wide range of novel methods. The objective of this study is to qualitatively assess the potential for increasing the value added in the Dutch dairy production chain by developing future scenarios. Scenario development as a systematic way of thinking about the future has been used extensively in various sectors and disciplines in the past decades (Schoemaker, 1995; Swart *et al.*, 2004). In this article the method is used to explore future perspectives of the dairy production chain in the Netherlands. The scenarios describe different dairy production chains to help stakeholders to better adapt to the future. It is our intention to inform broadly and promote discussion, rather than to provide in-depth coverage. In line with Rotmans *et al.* (2000), the scenarios are presented as descriptions of different future images.

The Dutch dairy chain

The Netherlands is one of the largest dairy producers and exporters within the European Union (EU). In the last decade, its yearly milk production amounted to about 11 billion kg, having the bulk of it processed into cheese, butter, milk powder, fresh dairy products and specialties. Some 300 wholesalers and 6800 sales outlets are involved in the trade in and sales of dairy products. The dairy sector as a whole provides around 61,000 jobs, thereby playing an important role within the Dutch economy. Similar to many European countries, dairy farming in the Netherlands is characterized by a falling number of cows, a declining number of farmers, and an increasing level of farm technology and milk yield. Nowadays, the Dutch dairy sector comprises nearly 20,000 dairy farms with about 1.4 million dairy cows. In 2007, the average production per farm reached 520 tons of milk, the average number of cows per farm about 70 and the percentage of farms with 70 cows or more nearly 40 (Anon., 2007). In 2007, the average milk yield was about 7900 kg per cow per year, but milk yield of registered cows scored slightly higher. Holstein Friesian is the dominant breed in the Netherlands, accounting for more than 95% of Dutch dairy cattle. The average Dutch dairy diet nowadays contains about 30% fresh grass, the remainder being a mix of grass silage, maize silage, and concentrates.

The Dutch dairy sector is dominated by a co-operative structure and is one of the most consolidated in the world. Dairy co-operatives owned by dairy farmers have been in place since the early days of the dairy industry, and the farmers have been part of the process of consolidation over the past decades. Due to a recent merger, nowadays one major internationally oriented co-operative processes almost 80% of the milk delivered to factories. The Dutch dairy sector has a strong competitive international position and is among the world's major dairy exporters with an export value of around € 4.3 billion in 2007. Export revenues represent a large share of total annual sales by the sector. About 60% of Dutch dairy production is exported, the remaining part being consumed domestically. The EU is the most important export market, accounting for two thirds of the total dairy export value in 2007. Within the EU, most of the Dutch export goes to nearby markets in Germany, France, and Belgium, representing about 40% of the total export value in 2007 (Anon., 2007). Besides export, the Netherlands is also a major importer of dairy products, re-exporting much of these imports to EU countries and beyond. In 2007, total Dutch dairy imports valued more than € 2.3 billion (Anon., 2007).

In this study, the Dutch dairy production chain is considered as a case. Following the definition of Valeeva *et al.* (2005), who studied food safety improvement in the dairy production chain in the Netherlands, we considered the following stages: a feed production stage, a dairy farm stage, a processing-factory stage, and a retailer stage. Transportation between the stages is also considered, i.e., transport of compound feed to the dairy farm and transport of raw milk to the processing factory. Stages of catering and the actual consumption of milk and dairy products were not included. In addition to the chain description of Valeeva *et al.* (2005), an animal breeding stage is also considered in the present study.

Major trends and developments

Trends in the Netherlands

The contemporary trends affecting the Dutch dairy sector are in line with the aforementioned prevailing global trends. First, consumer preferences have changed in the Netherlands. In the last decade, the per capita consumption of milk and dairy products has dropped by 7% (Anon., 2007). Furthermore, the interest in the effects of diet on human health has recently increased because the composition of the Dutch diet has been found unfavourable (Van Kreijl *et al.*, 2006). The proportion of obese people has doubled to 10% in the last 25 years, and is predicted to increase to 15% in the next two decades (Van Kreijl *et al.*, 2006). These authors also argue that 10% of all deaths in the Netherlands are attributable to poor diet and 5% to being overweight. They claim that loss of health resulting from unfavourable diet could be largely avoided by means of dietary interventions. Such interventions reveal great opportunities for the Dutch dairy sector. Improving the nutritional quality of milk and dairy products could contribute to a more favourable human diet, given that milk and derived products are important sources of nutrients in human diets (Lock & Bauman, 2004; Haug *et al.*, 2007).

Second, the continuous pressure on the Dutch dairy sector for a more efficient production has recently increased too. The price of dairy commodities has been volatile over the last decade, forcing the sector towards a higher cost-efficiency and consolidation. As a result of this price pressure, the number of dairy farms has declined by nearly 30% between 2000 and 2007 (Anon., 2007), and the number of dairy processors decreased by more than half between 1985 and 2000 (Ramirez *et al.*, 2006). In addition to volatile prices, there are other factors that can force the Dutch dairy sector towards a more cost-efficient production and further consolidation. In particular, the production of raw milk, which has been limited since 1984 by production quotas in the EU, is likely to become free of restrictions in the coming years; while the dairy trade is also likely to become less protected by European and national trade policies (Dillon *et al.*, 2008). These policy changes are likely to continue to push milk prices downwards and necessitate increased efficiency and scale at farm and processing level to maintain profitability (Dillon *et al.*, 2008).

Third, the Dutch dairy sector is strongly influenced by environmental concerns such as reducing energy use, decreasing nutrient losses, and lowering GHG emissions. Although the dairy sector in the Netherlands has achieved a remarkable improvement in energy efficiency since the mid-1980s (Ramirez *et al.*, 2006), there is still a need for further progress according to a voluntary agreement between the dairy sector and the Dutch government. The Dutch dairy sector and the Dutch Ministry of Economic Affairs signed an agreement in 1994 to increase energy efficiency by 20% by the year 2000 (from 1989 values). The current requirement is an annual 2% reduction in energy use until 2020. Moreover, dairy farming in the Netherlands is highly nutrient-intensive, requiring environmental policies to restrict undesirable leaching of nutrients (Van Bruchem *et al.*, 1999) and high emissions of GHGs (Freibauer, 2003). European and national policies have been implemented to tackle these environmental problems (Henkens & Van Keulen, 2001), forcing farmers to improve nutrient use (Berentsen & Tiessink, 2003; Groot *et al.*, 2006; Schils *et al.*, 2006). Nevertheless, further changes in individual farm management towards more effective and less polluting strategies are necessary (Ondersteijn *et al.*, 2002).

In the following section, some of the major technological developments in the dairy production chain are described. Actual developments and future directions in technologies are discussed, with special attention to those that relate to the above presented trends. Covered domains include the fields of animal breeding and genetics, animal nutrition, milk segregation, milk storage, livestock waste management, food preservation, and food packaging. We touch on many areas, each of which is worthy of a full review in itself, and hence it is necessary to treat each area rather superficially.

Developments in animal breeding and genetics

Research has suggested selective breeding as a tool for farmers to meet specific consumer or industrial demands by exploiting the genetic variation underlying the differences among cows. First, technological properties of raw milk can be improved by selecting variants of milk proteins that are preferable for dairy manufacturing (Dalgleish, 1993; Ng-Kwai-Hang & Grosclaude, 2003). Second, nutritional quality of raw milk can be improved, because the milk fatty acid (FA) composition can be improved by selective breeding, having two main directions. One way is to select cows for an individual milk FA or for a group of milk FAs, as several milk FAs have been shown to have genetic variation (moderate to high heritabilities that tend to be lower for unsaturated FAs) within various cattle breeds (Soyeurt *et al.*, 2007; Bobe *et al.*, 2008; Stoop *et al.*, 2008). Another way is to select cows for particular genotypes of two recently suggested candidate genes: the *DGAT1* gene (Schennink *et al.*, 2007) and the *SCD1* gene (Moioli *et al.*, 2007; Macciotta *et al.*, 2008; Schennink *et al.*, 2008). The *DGAT1* gene plays a key role in triacylglycerol synthesis; whereas the *SCD1* gene codes for a key enzyme in the cellular biosynthesis of monounsaturated FAs. Polymorphism of these genes has been shown to affect milk FA composition in various cattle breeds, thereby implying that selection for the favourable gene variants can be used in changing the fat composition of cow's milk.

Developments in animal nutrition

By using novel cow diets, composition of raw milk can be changed to meet consumer or industrial demand. Feeding supplements can change milk fat composition (Chilliard *et al.*, 2000; Jenkins & McGuire, 2006) or elevate the level of valuable micronutrients (Knowles *et al.*, 1999; Givens *et al.*, 2004; Knowles *et al.*, 2006) to enhance human health benefits. Also, feeding regimes based on fresh herbage and outdoor grazing have been suggested to favourably change the FA profile of raw milk (Elgersma *et al.*, 2006). In addition to changing milk fat composition, specifically designed cow diets can be used to increase the concentration of favourable protein fractions (Guinee *et al.*, 1998; Murphy, 1999; Auldist *et al.*, 2007) to improve the nutritional quality or the manufacturing properties of raw milk. Changing milk composition by feeding supplements, however, is complex because the transfer of the favourable FAs to milk is significantly limited by several factors. These factors include destruction by ruminal micro-organisms, poor rates of intestinal absorption, and deposition in adipose tissue rather than in mammary fat (Jenkins & McGuire, 2006). So the efficiency of transfer of desired nutrients from feeds to milk needs to be improved in the future. Furthermore, because animal nutrition has an impact on environmental sustainability, recent research in animal nutrition has been geared towards opportunities to mitigate the environment polluting effects of cattle diets (Frank *et al.*, 2002; Dijkstra *et al.*, 2007; Arriaga *et al.*, 2009). Likely domains of future research include improving digestibility of dietary components, optimizing ruminal fermentation, improving use of N and P for the animal's benefit and reducing environmental pollution, and a further understanding of the nutritional requirements of animals (Eastridge, 2006).

Developments in milk segregation

On-farm milk segregation presents another opportunity for the farmers to produce value-added products. First, segregation of cows within a herd could be an option to produce different milk types, and this method may be further improved by using genetic selection (Dooley *et al.*, 2005b). Second, by using milking parlours or automated milking systems (AMS) equipped with new biosensor technologies, the natural variation amongst cows could be exploited. To date, biosensors in milking systems can measure several milk components indicating the cow's fertility (Mottram *et al.*, 2002), metabolic and nutritional status (Jenkins *et al.*, 1999; Mottram *et al.*, 2002), and health (Reinemann & Helgren, 2004). Developments point towards milking systems designed to measure milk composition (Reinemann & Helgren, 2004). Short-wave near-infrared spectroscopy (Tsenkova *et al.*, 1999) and mid-infrared spectrometry (Soyeurt *et al.*, 2006) could be good alternatives for measuring milk composition online. In short, the availability of milking systems equipped with novel biosensors would allow the segregation of different types of milk at the farm level on a daily basis.

Developments in milk storage

Milk storage is relevant because the storing conditions of raw milk can affect the yield, quality, shelf life, and sensory values of the derived dairy products (Ma *et al.*, 2000; Barbano *et al.*, 2006). Therefore, the improvement of raw milk storage during milk collection and on the farm could mean shelf life extension and improved safety, as in these stages of the dairy production chain significant changes may occur in raw milk due to microbial growth (Hotchkiss *et al.*, 2006). A recently investigated way to improve milk storage is the use of carbon dioxide (CO_2), a method that inhibits the growth of micro-organisms by displacing oxygen, lowering the pH, and directly affecting their metabolism (Hotchkiss *et al.*, 2006). To inhibit bacterial growth significantly the CO_2 can be added directly to the raw milk (Ma *et al.*, 2003; Martin *et al.*, 2003), to the storage atmosphere (Dechemi *et al.*, 2005), or by applying low CO_2 pressure (Rajagopal *et al.*, 2005; Hotchkiss *et al.*, 2006).

Developments in livestock waste management

Over the last decades, there has been growing concern about environmental, nuisance, and health issues of satisfactory livestock waste treatment in countries with concentrated livestock production (Burton & Turner, 2003). Developments in manure and waste management can help improving farming attributes that are important in ecological sustainability. These sustainability attributes include waste disposal, air and ground-water pollution, eutrophication, and energy usage (Van Calker *et al.*, 2005a). In recent years, amongst other treatments, the method of anaerobic digestion (AD) with utilization of biogas is increasingly recognized as a promising technology to produce renewable energy and to reduce environmental emissions (Abraham *et al.*, 2007). In dairy farming, AD (also known as fermentation) has successfully been applied in many countries to recycle farm animal manure and organic wastes (Harikishan & Sung, 2003; Kaparaju & Rintala, 2003; Uludag-Demirer *et al.*, 2008). It is a biological method relying on the growth and activity of specific groups of microbes. AD technology not only reduces the environmental impact of the treated farm manure and waste but also generates methane as a useful by-product. Overall, the advantages of the AD method include, amongst other things, the production of biogas, reduction of odours, reduction of pathogens in slurries, improving the fertilizing value of slurries, and reduction of GHG emissions (Burton & Turner, 2003).

Developments in food preservation

Traditional thermal inactivation techniques can cause adverse changes in the nutritional (Andersson & Oste, 1995), organoleptic (Nursten, 1995), or technological properties (Singh, 1995) of milk. Consequently, the replacement of these methods has been widely researched due to growing consumer demand for minimally processed fresher foods. Several non-thermal methods of processing milk and milk products have been investigated in recent years. The methods include membrane microfiltration (Rosenberg, 1995; Saboya & Maubois, 2000; Brans *et al.*, 2004), high-pressure treatment (Messens *et al.*, 2003), pulsed electric field processing (Bendicho *et al.*, 2002; Sampedro *et al.*, 2005), ultraviolet treatment (Reinemann *et al.*, 2006; Altic *et al.*, 2007; Matak *et al.*, 2007), ultrasound processing (Villamiel & De Jong, 2000; Piyasena *et al.*, 2003; Knorr *et al.*, 2004), and the addition of carbon dioxide (Loss & Hotchkiss, 2003; Hotchkiss *et al.*, 2006; Garcia-Gonzalez *et al.*, 2007). Although the new technologies are promising, implementing them on a large scale in the dairy sector is a problem because of their high costs.

Developments in food packaging

Innovative food-packaging concepts have emerged due to consumer demand for fresher foods and due to new retail and distribution practices such as centralization, internet shopping, and globalization (Vermeiren *et al.*, 1999). Active and intelligent packaging systems have received most attention. Active packaging (AP) changes the condition of packaged food to improve shelf life, food safety, or sensory values while maintaining quality (De Kruijf *et al.*, 2002). AP technologies change interactions between the food, the package, and the package headspace by applying some physical, chemical, or biological actions (Rooney, 1995; Brody *et al.*, 2001). Intelligent packaging (IP) includes packaging concepts that can perform intelligent functions to facilitate decision-making to improve shelf life, food safety, and quality by providing information and warning about potential problems (Yam *et al.*, 2005). Primary value of IP systems is the ability to communicate, which is achieved by using smart packaging devices. One such device is the radio frequency identification (RFID) tag, which has been successfully applied at product level in the dairy sector (Regattieri *et al.*, 2007). RFID tags offer great potential for improving security, productivity, inventory control, and traceability in food supply chains (Wang *et al.*, 2006), and may also be integrated with various package indicators (time–temperature indicator, gas indicator, or biosensors). A number of AP and IP systems have been developed and successfully applied in many countries outside Europe. In the EU, their large-scale implementation requires regulatory amendments (Vermeiren *et al.*, 1999; De Kruijf *et al.*, 2002; Lopez-Rubio *et al.*, 2004).

Materials and methods

In this paper the method of scenario development is used to compose possible future situations for the dairy production chain in the Netherlands. Scenarios answer the question: "What can happen if the Dutch dairy production chain develops in a certain way?" Therefore, the scenarios aim at exploring the possible consequences of different future developments implied by the chain's strategic interests. The developed scenarios support a strategic orientation (Westhoek *et al.*, 2006) as they envision different futures that the stakeholders need to prepare for in order to establish a robust long-term strategy. According to Van Notten *et al.* (2003), the developed scenarios are: *descriptive* – exploring possible futures; *forecasting* – exploring different developments starting from the present; *institution-based* – considering the development of the dairy production chain; *short-term* – considering a time span ranging from 5 to 20 years; and *national* – focusing only on the Netherlands. Regarding the process design, scenarios are: *qualitative* – presented in a narrative way without formal models; and *combining participatory approach and desk research* – constructed by collecting data from experts, stakeholders, and the literature.

The involvement of stakeholders and experts, which is an increasingly vital data collection method in recent scenario studies (Van Asselt & Rijkens-Klomp, 2002; Van Notten *et al.*, 2003), played a key role in developing the scenarios. In 2007, a workshop was organized to investigate the potential for increasing the value added in the Dutch dairy production chain. It was inspired by the demand of chain stakeholders to improve and protect its competitive position. The workshop lasted two days, and to optimally exploit opportunities there was one week between the first and the second day. As good group support and facilitation are important (Kwok *et al.*, 2002), the workshop took place in the T-Xchange Cell <http://www.txchange.nl>, Twente University, the Netherlands. This is a specially designed 'innovation-inducing' environment that offers opportunities for accelerating and enhancing innovation and development processes. T-Xchange Cell can be considered a group support system, equipped with computer-based technology, involving groups of participants and facilitation (Ackermann *et al.*, 2005).

Two main groups of participants were invited: stakeholders from the dairy production chain (8) and dairy experts (6). They were selected on the basis of their expertise and experiences in the dairy sector. Participants represented dairy co-operatives (4), a major livestock improvement company (2), dairy farmers (2), the national dairy organization (1), universities (3), and an organization linking science and business (2). Except for the overall objective, no information was given to the participants beforehand, so as to avoid any bias in the results. Under the guidance of the facilitation team (8), the participants took four successive steps, where each step resulted in information for the next step. The steps included: (1) becoming acquainted with the problem definition and objective; (2) identifying the current trends and developments by brainstorming to let participants broaden their solution space; (3) constructing innovative scenarios based on the objective and on the outcomes of the brainstorming; and (4) visualizing the scenarios to enhance the development of ideas and communication among the parties. The first two steps were taken on the first day. The first step comprised an opening plenary session, and was followed by a group session (second step) where the trends and developments were discussed. The third step and the fourth step took place on the second day, when the scenarios were developed in a group session (third step), followed by a plenary session in which the scenarios were visualized as the last step. During the group sessions the participants were divided into two groups to equally represent all stakeholders in each group.

Results

The outcomes of the workshop were a summary of the scenarios, the minutes of both days' sessions, mind maps, and pictures. Using these outcomes, three scenarios were developed that are relevant for the Dutch dairy production chain to increase the value added in the coming years: (1) scenario *Designer Milks*, (2) scenario *Active Logistics*, and (3) scenario *Glasshouse-Cow*. Below, the summaries of the extracted scenarios and their implications are presented.

Scenario Designer Milks

Designer Milks envisions the prevalence of producing raw milk with specific characteristics, meaning that farmers no longer produce commodity milk. In this scenario the Dutch dairy production chain has a keen interest in improving the intrinsic and perceived values of milk. As initial steps in this direction have already been taken in the Netherlands, *Designer Milks* can be regarded as a baseline scenario.

In *Designer Milks* there is differentiation among farms, that is, farms deliver different types (in terms of taste and quality) of milk. Farmers use novel methods to produce specialized raw milk, including selective breeding, tailor-made cow diets, and on-farm milk segregation. First, biotechnology is intensively used to improve the dairy herds; therefore the cattle genome has been further explored, enabling breeders to target specific genes in order to choose milk types that consumers or industries want. Transgenic methods are not used, as they are technologically inefficient, expensive, and rejected by consumers. Second, cows' diets are based on fresh herbage and supplemented with a number of tailor-made feeding additives to specifically change the composition of raw milk. Third, AMS is widely used in the Netherlands, and milking systems are equipped with biosensors that measure milk composition. Farmers, therefore, segregate different types of milk on a daily basis.

The differentiation of raw milk has two main objectives. First, some farms produce milk with altered fat composition by lowering the fat fractions that are proven to be injurious to human health, and by increasing the healthy fatty acids. Raw milk with healthier fat is used for the production of milk and derived dairy products that decrease the risk of cardiovascular diseases. Second, some farms produce milk with desired concentrations and variants of major milk proteins; this type of milk is destined for cheese production or ingredient production. Developments in this direction are desirable as cheese production plays a central role in the Netherlands' dairy production chain: about 50% of the milk is used for cheese manufacturing, and cheese exports represent more than half the chain's total export value.

This scenario assumes realization in 5 to 10 years. The fastest way to produce differentiated milk is by changing the cows' diets. Feeding supplements that change fat composition are already marketed in the Netherlands, and further developments in this area are expected. Animal breeding to achieve this scenario will take longer. Although promising results in animal selection supported by genetic tools are available, it will take several years before a breeding decision affects the cows in the herd.

Scenario Active Logistics

Active Logistics envisions the Dutch dairy production chain with innovative logistics for different milk flows. A new set-up for the dairy supply chain is established with the purpose of producing fresher and more customized milk and derived products with improved shelf life.

In *Active Logistics* the length of the dairy chain is reduced to improve overall quality and freshness. First, new methods are used for storing and transporting milk. Raw milk is no longer stored for two or three days at the dairy farms without any treatments prior to collection. During on-farm storage, active storage facilities are used to inactivate bacteria in raw milk, aiming for early preservation to improve shelf life and food safety. Also, collection of raw milk from farms to dairies has changed. Tankers no longer carry merely one milk type but can collect different milk types from one or more farms separately yet simultaneously. Tankers are equipped with a specifically designed container-frame to carry containers accommodating different types of milk. Active containers are used on tankers for preserving the milk, thereby further improving shelf life and overall quality during collection. As a result of the early preservation on farms and during milk collection, the processing of raw milk in dairy plants no longer involves steps of food preservation. Different milk flows are delivered directly for the manufacturing of different products.

Second, novel solutions are applied in packaging and distributing dairy foods to further reduce the chain and to enhance consumer involvement. Food packages combine active and intelligent features by, for example, adding bacteria to the milk to sour it according to customer preferences. Packages are compatible with a new generation of household equipment used by consumers to customize milk and dairy products in their homes by adding fragrance, taste, or health-promoting substances. Packages also have intelligent properties (RFID tags) indicating the origin of the milk used. In short, by using novel packages, the processing of raw milk into end products is further reduced, and consumers purchase dairy foods that originate from their preferred region or farm. Furthermore, novel product delivery concepts are implemented. Dairy products are purchased via internet from dairy processors who deliver directly to consumers in a 'cooled mailbox'. This new way of dairy distribution has two major effects. First, the retail trade in the dairy chain is reduced. Second, as dairy processors merchandize their products directly, the chain obtains more information on consumer preferences, enabling the production of product portfolios that better respond to the changing market.

The scenario *Active Logistics* could be realized on a somewhat longer term than the previous scenario. More specifically, setting up an integrated logistic and decision support system in the dairy production chain is expected to become feasible within the next 10 to 15 years.

Scenario Glasshouse-Cow

Scenario *Glasshouse-Cow* describes the Dutch dairy production chain with ecologically sustainable dairy farming. Central concepts are the prevention of the on-farm losses of natural resources, the production of bioenergy, and the enhancement of animal welfare.

In *Glasshouse-Cow* the dairy farms are equipped with novel housing facilities and new on-farm technologies. Cows are kept indoors in order to strengthen the principle of closed circuit by controlling the flow of materials such as gas, water, electricity, fodder, milk, manure and biological wastes. Dairy farms are equipped with anaerobic fermentation units (digesters) to convert surplus manure and organic wastes into biogas. The digested manure is used as fertilizer in crop production, which significantly reduces the use of inorganic fertilizers. Also, the methane resulting from the cows' enteric fermentation is captured by the internal ventilation system and used in biogas production. The produced biogas is utilized not only for heating and cooking on-farm but also for supplying dairy factories with biogas via existing natural gas networks. In addition to biogas, the roofing materials of the housing facilities on the farms can collect and convert solar energy into a usable energy source. The production of biogas from manure and biological wastes, together with the usage of solar energy has a twofold benefit. First, the considerable environmental benefit from reducing not only the emissions of odour, ammonia, and greenhouse gases into the air, but also nutrient leaching and surface run-off. Second, the economic benefit from providing alternative and renewable energy sources. By using such energy sources, the scenario *Glasshouse-Cow* envisions dairy farming systems that are self-sufficient in energy and no longer rely on fossil fuels.

Furthermore, because the cows are kept indoors, the housing conditions of the animals are significantly improved. Dairy farmers no longer keep cows in conventional dairy stables. Instead, similar to the circumstances in which zoo animals are kept, the novel dairy housing facilities are designed to resemble the cows' natural environment. The novel stables enclose the cows and their environment into one housing complex, where animals walk and graze inside a building constructed to resemble a pasture. Also, novel floors and lighting are implemented that are tailored specifically to the needs of the cows. Furthermore, the housing complex is covered with a transparent material to make dairy farming visible to consumers, thereby stressing the importance of the people behind the initiatives attached to animal welfare. In this scenario, the most important message to society is that milk and dairy products are healthy and produced in a natural and environmentally sustainable way.

In the scenario *Glasshouse-Cow* dairy farming significantly reduces energy usage, nutrient losses, and greenhouse-gas emissions, while it enhances the welfare of the cows. Eventually, these achievements towards an ecologically sustainable dairy farming are communicated to consumers who are informed about the origin of the product they consume. The visions of this scenario might be the most futuristic amongst the presented scenarios. Although initial steps in the directions outlined in the scenario have been taken already in the Netherlands (including research and pilot projects), presumably the *Glasshouse-Cow* concepts could be implemented on a national scale no sooner than two decades from now.

Major implications of the scenarios

In this section, the domains of the major implications of the developed scenarios are discussed in a qualitative manner. That is, the potential consequences are assessed without going into quantified details. The workshop participants addressed the topics economic implications, chain organization, risk factors, ethical aspects, and environmental implications.

Economic implications

In *Designer Milks*, to preserve economically sustainable dairy farming, the health of the cows is crucial. Therefore, the new breeding and feeding strategies have to consider whether or not they have any adverse effects on the cows' fertility, susceptibility for diseases, and longevity. *Active Logistics* involves large initial investments for the different actors within the dairy production chain. The farmers need to purchase active storage facilities, while dairy processors need to invest in novel milk containers and packaging systems. The direct delivery of dairy products to consumers entails further transportation costs for dairy processors. It is important to note that the storage and collection of different milk flows are important aspects in both *Designer Milks* and *Active Logistics*. In the scenario *Glasshouse-Cow* farmers need to invest in new housing facilities and implement bioenergy-producing machinery. In turn, however, economic benefits can be realized due to energy savings from the use of generated biogas, sales of organic by-products, and reduced use of inorganic fertilizers.

Chain organization

First, in each scenario, dairy farmers need financial incentives to be compensated for the extra on-farm costs, lost revenues, and risks. So the dairy processors have to modify their payment schemes to reward the specialized composition in *Designer Milks*, the early preservation in *Active Logistics*, and the ecological sustainability in *Glasshouse-Cow*. However, it is important that not only incentives but also government policies can force developments. For example, the introduction of new standards for milk composition or new subsidy programmes for biogas production could facilitate novel management strategies. Second, *Active Logistics* has a profound impact on the organization of the dairy production chain due to the reorganized logistics, the reduced processing of raw milk into dairy products, and the new ways of distributing dairy foods. However, these changes in the dairy chain organization might be complicated given its long establishment in the Netherlands. Changing the set-up of the Dutch dairy chain not only demands extensive consultation but also audacity and leadership.

Risk factors

The three scenarios inherently involve uncertainties such as new production technologies and forecasted demand, expenditures, and revenues. Also, the discontinuation of a new strategy due to technology developments, decreased consumer demand, or oversupply represents uncertainty. This uncertainty is a critical point because different new methods require different initial investments and have different learning periods. Therefore, in the case of discontinuation, the break-even premiums required to cover the initial investments and lost revenues might become substantially higher. Another risk factor is the farmers' technology adoption rate, which is important in determining the introduction and volume of production. Technology adoption rate can be influenced by volatile food (milk) prices. More specifically, increasing food prices are likely to lead to higher profitability, thereby lowering the farmers' incentives to adopt innovation strategies; whereas decreasing food prices are likely to have the opposite effect. Moreover, the consumer acceptance of the novel ways of producing milk and dairy products is uncertain. It is especially important with regard to the foreign markets of the Dutch dairy chain, given that some 70% of the Dutch dairy production is exported.

Ethical aspects

In each scenario the implemented changes in the dairy chain have to be accepted by the Dutch consumer. In *Designer Milks*, milk with special characteristics should not be produced at the expense of the health and welfare of the dairy cows. In the case of *Active Logistics*, direct dairy distribution via internet requires regulatory changes to allow dairy processors to handle personal purchase information. For *Glasshouse-Cow*, the society needs to accept that dairy cows are kept indoors, so public discussion is necessary with Dutch consumers and community organizations that traditionally prefer to see the animals kept outside. The Dutch consumer has to be informed not only about the ecological advantages of keeping the animals indoors but also about the improved housing conditions that are specifically tailored to the needs of the animals.

Environmental implications

Future dairy production in the Netherlands has to be ecologically sustainable, and this issue has to play a key role in developments in the Dutch dairy chain. In *Designer Milks*, therefore, the application of novel cow diets to produce differentiated raw milk should not lead to additional nutrient losses and GHG emissions. With *Active Logistics*, the reduction of the dairy supply chain by early preservation, joint transportation of different milk flows, and direct delivery to consumers can substantially change energy use in the dairy sector. With regard to the environmental considerations, the scenario *Glasshouse-Cow* is the most desirable as it aims at the creation of environmentally sustainable dairy farming.

Discussion

Scenario Designer Milks

The scenario *Designer Milks* builds on developments in farming practices such as selective breeding, animal nutrition, and farm management. In this scenario, growing consumer demand for dairy products with enhanced nutritional values is addressed by producing milk with a healthier milk-fat composition. However, scientific research is needed before deciding which fat fractions will be decreased and which increased, given that the exact impact of some fatty acids on human health is not known. German & Dillard (2006) and Steijns (2008) provide a thorough overview of the existing knowledge on how intake of dairy products may influence health, thereby offering opportunities for potential improvements. With respect to improving milk's cheese-making properties, it serves the growing aim of the processing companies for a more cost-efficient production.

In the literature a number of strategies are discussed for producing milk with specialized characteristics as improved raw materials (Boland *et al.*, 2001).

Because the scenario *Designer Milks* considers selective breeding, a relevant aspect to consider in this scenario is the changes in breeding objectives. As discussed earlier, the new breeding strategies have to consider their effects on the cows' health and welfare. Therefore, social and ethical aspects of animal production have to be included when defining the novel breeding goals because of increased public concern (Olesen *et al.*, 2000; Gamborg & Sandøe, 2005; Oltenacu & Algers, 2005). Another important aspect is the impact of changing raw milk composition on product quality. Regarding designer milks with improved health benefits, it has been shown that milk with a more unsaturated fatty acid profile can successfully be processed into cheese and butter with softer textures and acceptable organoleptic and storage properties (Middaugh *et al.*, 1988; Stegeman *et al.*, 1992; Ryhänen *et al.*, 2005). Regarding designer milks for more efficient dairy manufacturing, Guinee *et al.* (1998) found that changing protein composition to improve cheese production has no effect on the functionality (melt time, flowability, stretch and viscosity) of the end product.

Scenario Active Logistics

By reducing the length of the dairy supply chain in the scenario *Active Logistics*, the Dutch dairy chain reacts to the increasing demand for minimally processed fresher foods with improved sensory values and acceptable shelf life. The scenario builds on the advances in the following segments of the food industry: milk storage, dairy packaging systems, and food delivery practices. The visions for novel ways of distributing dairy foods are in line with the visions of Sonesson & Berlin (2003), who describe scenarios for a future milk supply chain in Sweden. By studying the effects of different scenarios on the environment, Sonesson & Berlin (2003) found that the increasing demand for more and fresher products affects the environmental impact of several parts of the dairy chain.

As discussed above, the storage and collection of different milk flows are important aspects to consider in the scenario *Active Logistics*. There are two distinct settings. First, farmers can be fully specialized in producing one type of milk, and thus no extra storage facilities are needed on the farm. However, because the locations of the participating farmers might become more dispersed, the milk tanker collection route would have to be modified, thereby increasing transportation costs. Second, farmers could produce commodity milk as well as specialized milk. Consequently, extra storage facilities may be required to segregate different milk types on-farm and during collection, and the transportation costs are likely to grow. Dooley *et al.* (2005a) studied the effects of producing and segregating different types of raw milk at farm level on transportation costs for dairy farmers in New Zealand. They found that the collection of two types of milk increased the transportation costs by 4.5 to 22%.

Scenario Glasshouse-Cow

In the scenario *Glasshouse-Cow*, the Dutch dairy chain addresses the problems of nutrient losses, GHG emissions, energy consumption, and animal welfare. These issues are challenges for the nutrient-intensive Dutch dairy farming in achieving ecological sustainability (Van Calker *et al.*, 2005a). Other possible strategies to cope with the environmental concerns of future dairy chains have also been studied in the literature. Sonesson & Berlin (2003) developed different scenarios for the Swedish dairy chain to explore the environmental impacts of future dairy chains. They found that packaging materials used, energy usage, and the transportation of the dairy products to households are important factors when improving the dairy chain from an environmental point of view. Furthermore, they demonstrated that any consideration of the environmental effects of the milk supply chain must consider the entire chain. However, Sonesson & Berlin (2003) did not include agriculture in the analysis. Scenario *Glasshouse-Cow*, therefore, offers another pathway to improve the ecological sustainability of the dairy chain by changing the conventional ways of dairy farming. Van Calker *et al.* (2005b) studied the sustainability of different dairy farming systems in the Netherlands, including the application of an already existing commercial approach in Dutch dairy farming that balances between economic growth, social progress, and environmental protection. They suggested that a holistic, bottom-up strategy, in which the partners and stakeholders of the dairy chain co-operate, is needed to develop dairy production in a more sustainable way.

In scenario *Glasshouse-Cow*, the treatment of livestock waste and the utilization of biomass have important economic consequences. Tangible economic benefits can be expected because good livestock waste treatment can become a new income source for farmers (Burton & Turner, 2003; Weiland, 2006). It is unlikely, however, that the treatment systems can fully cover their costs related to investments, labour, and land. In the European countries, therefore, in most cases net financial earnings are only possible with grants supporting the initial capital investments and with high valuation of the produced energy (Burton & Turner, 2003). Livestock-waste treatment systems are overall financial charges to the farmers, and thus need financial compensation to remain competitive. Consequently, pressuring environmental regulations and supporting grants by local and national governments are likely to remain the major forces in promoting such environmental technologies in the EU (Burton & Turner, 2003; Abraham *et al.*, 2007).

Future research

The three scenarios address different trends and build upon different technological advances. The present study qualitatively discusses the implications of the developed scenarios. In future studies, however, it will be desirable to quantify the economic consequences, in addition to a qualitative assessment. Because the field of value-added dairy methods is relatively new, so far the quantitative economic modelling has been limited to the methods described in our baseline scenario, *Designer Milks*. More specifically, the economic consequences of producing raw milk with specific characteristics have been modelled. Maynard & Franklin (2003) studied the implementation of novel cow diets to produce dairy products rich in conjugated linoleic acids (CLA) for small-scale American dairy farms. They showed that the farmers would break even if the retail premiums of the high-CLA products were less than 15% of their typical retail prices.

These premiums were comparable with the results of the willingness-to-pay surveys, showing great market opportunities for small-scale niche dairy product manufacturing using advances in animal nutrition. Dooley *et al.* (2005b) investigated the cost implications of implementing novel breeding strategies for New Zealand dairy farmers to produce two particular types of milk: milk with 'whiter milk fat' and milk with improved cheese-making properties. In the case of the former milk type, they found that farmers would require from 38% higher milk fat prices to break even; whereas, in the case of the latter milk type the necessary premium ranged from 3 to 5% for both milk fat and protein. However, there are still aspects of producing raw milk with specialized values that have not been investigated. Certainly important are the effects of novel production strategies on cow replacement decisions, given their high economic importance to dairy owners and managers (Dijkhuizen & Stelwagen, 1988; Lehenbauer & Oltjen, 1998). So future quantitative research is needed to investigate the effects of different strategies on cow replacement, which can be successfully done by formal model calculations (Jalvingh, 1992).

Conclusions

For the dairy chain in the Netherlands the pursuit of continuous innovation and the delivery of value-added products to consumers will be critical to ensure long-term market development in an increasingly competitive industry. The objective of this paper was to help stakeholders to better adapt to the future. Our study shows that developing scenarios using a participatory approach allows for exploring future strategies for the dairy chain. By organizing a workshop involving industry stakeholders and experts, we developed three scenarios: *Designer Milks*, *Active Logistics*, and *Glasshouse-Cow*. They address major trends affecting the Dutch dairy sector, including changing consumer preferences, increasing pressure for more cost-efficient production, and rising environmental concerns. The scenarios describe different dairy production chains in a rather extreme manner; that is, depicting the outer boundaries of what is possible to ensure that the differences between them stand out clearly. Not every vision is considered likely to occur. Rather, the scenarios indicate directions in which the dairy chain in the Netherlands might develop in the next 5 to 20 years. Although these directions are discussed separately, the scenarios are not necessarily mutually exclusive alternatives; different developments may occur simultaneously. The scenarios also show that when improving the dairy sector it is important to consider the entire chain, and hence concerted and co-ordinated actions by the various stakeholders are necessary. The study is an initial step in assessing the potential for increasing the value added in the Dutch dairy production chain. Further studies quantifying the consequences of different scenarios are necessary.

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